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THE IMPACT OF COLLISION AVOIDANCE SYSTEMS ON DRIVER BEHAVIOR AND TRAFFIC SAFETY: PRELIMINARIES TO STUDIES WITHIN THE "GIDS"-PROJECT

12

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Title:	The impact of collision avoidance systems on driver behavior and traffic safety: Preliminaries to studies within the "GIDS"-Project
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SUMMARY

This report reviews the essential considerations in the design of anti-collision systems for use in road traffic, in terms of the expected effects on driver behavior and, consequently, on traffic safety.

The two critical questions that should be answered before any CAS could function in a sensible way are:

(1) What is the criterion for system activation?

(2) What action will subsequently have to be performed?

Different criteria for activation, while all in temporal terms, will give rise to different rates of alarms and of false alarms. A priori calculations are given for fixed time criteria, time-to-collision criteria, and worst-case criteria. A time-to-collision criterion must a priori be judged to be most adapted to "natural" driving behavior.

With respect to the actual action to be undertaken, the choice is among different levels of system take-over, where the variation is from "none" to "total". Although total take-over by an automatic device sounds attractive, there are difficulties associated with it which have already been identified in other forms of man-machine interaction, e.g., behavioral changes counteracting the favorable effects to be obtained by automation.

Empirical evidence will have to assist in the ultimate decision of what level of take-over should be considered optimal.

KEYWORDS: NETHERLANDS, COLLISION AVOIDANCE, BEHAVIOR, LAND TRANSPORTATION, TRAFFIC.

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Het effect van anti-bots systemen op bestuurdersgedrag en op de verkeersveiligheid

W.H. Janssen

SAMENVATTING

Dit rapport bespreekt de te verwachten effecten van anti-bots systemen voor wegvoertuigen in termen van bestuurdersgedrag en daarmee ook in termen van verkeersveiligheid.
Er zijn twee belangrijke vragen die beantwoord moeten worden willen anti-bots systemen zinnig geacht kunnen worden:
(1) Wat moet het criterium zijn voor activatie van het systeem?
(2) Welke actie moet er vervolgens uitgevoerd worden?
Alle denkbare criteria voor systeem-activatie zullen resulteren in "false alarms". Op grond van een vergelijkend overzicht van criteria kan geconcludeerd worden dat een "time-to-collision" criterium het meeste zal aansluiten bij het natuurlijke rijgedrag.
De daaropvolgende actie kan, in meerdere of in mindere mate, onder automatische controle van het systeem staan. De daaraan verbonden problemen worden besproken, met name de te verwachten gedragsmatige tegenkoppelende reacties zoals die zich ook bij andere vormen van automatisering voordoen. Er valt nog geen conclusie te trekken over de optimale mate van automatisering zoals die in anti-bots systemen zou moeten worden toegepast.
Het rapport besluit met een beschrijving van het in het kader van het GIDS-project te verrichten onderzoek naar de gedragsmatige aspecten van anti-bots systemen.

1 INTRODUCTION

The GIDS-project, part of the DRIVE-programme of the European Community, has as its overall objective to determine the requirements and design standards for a class of intelligent co-driver systems which will be maximally consistent with the information requirements and performance capabilities of the human driver.
Central to a co-driver system as envisaged in the GIDS-project thus is the notion that all information that can and will be obtained by the advanced electronic devices of the future must be kept in manageable form - manageable, that is, to the driver.
To develop reasonable forms of information management one needs knowledge of how drivers perform the different subtasks that can be distinguished within the driving task, how drivers presently succeed in integrating these subtasks, and how they can be assisted in doing so successfully in the future.
One of the essential subtasks in driving, and therefore an issue in GIDS, consists in dealing with other vehicles on the road. This is commonly indicated as the "manoeuvering" level of the driving task. Collisions with other vehicles are pertinent evidence that this subtask is presently not always performed flawlessly.
A collision between a traffic participant and a fixed or moving obstacle occurs because the traffic participant did not note the obstacle at all or misjudged its movement. A ***collision avoidance system*** (CAS), correcting faulty user perception or decision-making, could reduce the frequency of collisions.
Thus, a CAS could well become part of the in-car environment and thereby contribute to the stream of information directed towards the driver. This is the motive for the study of a CAS as a component in a future "GIDS"-system.
The purpose of the present report is to provide a review of relevant evidence on CAS, to identify critical and unresolved issues regarding behavioral and safety consequences, and to derive a research line to be pursued as an element within the GIDS-project.
Although the technology of detecting the presence of obstacles and estimating their parameters of movement is by no means perfect yet (e.g., Kjellgren and Ödman, 1987; NASA, 1987; Wu and Tresselt, 1977) this report will assume that it will become so within a reasonable number of years. That is, it is assumed that it is possible to measure with sufficient accuracy:

(1) the ***distance*** to each and every object in the vicinity of the CAS-vehicle;

(2) the ***heading*** direction of the object relative to the line of movement of the CAS-vehicle (that is, the object's bearing angle);
(3) the ***relative velocity*** and ***acceleration*** of the CAS-vehicle with respect to the object in the bearing direction (from which can be deduced, if the CAS-vehicle's velocity is simultaneously measured, the ***absolute*** velocity of the object in the relevant direction).

What the level of technical perfection assumed to exist for the purpose of this report does not comprise is the ***qualitative*** recognition of what the object is. It appears to be unrealistic to hope that this will be achieved with sufficient accuracy in the foreseeable future.

2 THE ESSENTIAL QUESTIONS

Before a system capable of picking up the variables specified above can be designed and implemented there must be answers to the following questions:
(1) What is the ***criterion*** for activation of the system, that is, what will be considered a significant configuration requiring action?
(2) If action is deemed necessary what form will it have to have?

A feeling for what a CAS is basically aiming at may be obtained by noting that an average driver, at least in Western countries, has a collision with at least property damage every four or five years. Ideally a CAS should signalize that case and only that one. A few more cases may be added if narrow escapes are included. Even then, however, it will be clear that superb discriminative power will be required from a CAS. Such power is probably unattainable, because it would demand complete knowledge of what distinguishes collision from non-collision configurations in traffic well before the collision happens. Thus the system would not only have to recognize at a sufficiently early stage that a collision will follow if no action is taken, but it would also have to know that the driver will in fact not take evasive action in precisely this type of configuration.

Clearly what this means is that there will always be false alarms, the positive identification of critical situations which turn out not to be critical. The dilemma is that waiting longer, in order to make it sure that there ***is*** in fact a critical situation, reduces the chances of taking action that will be effective precisely in avoiding the collision: while signaling at a very early stage produces so many false alarms that this will undermine the trustworthiness of the system.

Nevertheless what must be the subject of research is to investigate what false alarm rates, and what types of false alarms, are acceptable - in some sense to be defined -, and to determine whether there exists an optimum in this respect.
After the problem of the best criterion has been solved there remains the question of what action should be performed, and by whom. The point in particular is whether the system should only give a warning to the driver in critical situations or whether it should go further than that, up to a total take-over by the system. The choice that is made in this respect will have major consequences for the ultimate success of a CAS.

3 CRITERIA FOR SYSTEM ACTIVATION

The elementary reasoning given in the introduction to this report is often illustrated by presenting Fig. 1. Here it is assumed that a driver's available time to react to an impending collision will, in some way, be effectively lengthened by a CAS, with a resultant reduction in the frequency of accidents that has been estimated to be in the order of 10% (Fontaine et al., 1989).

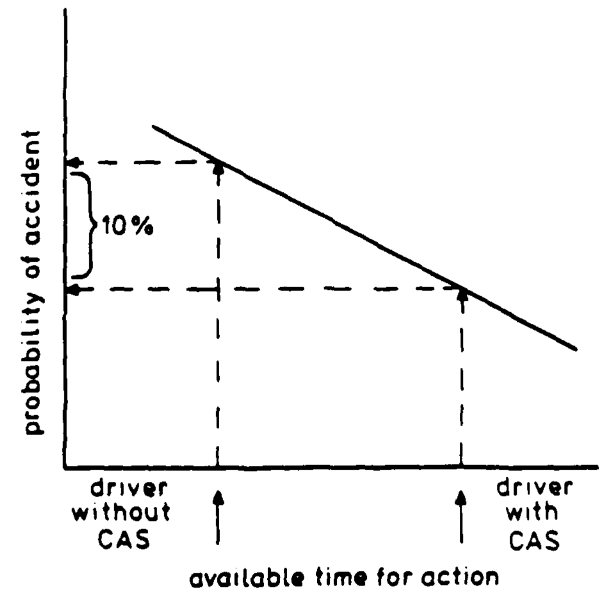

Fig. 1 Hypothetical effect of CAS on traffic safety.

It is never stated in this illustration in exactly what cases the driver should be warned (nor how the system should undertake further action).

Three more or less sensible criteria for system activation may be distinguished. These are:

(1) A *fixed* criterion in *terms of absolute time, that is*, the unconditional activation of the system by any obstacle that is within a certain time "radius" of the CAS-vehicle (in case of a longitudinal CAS: that is in a position that will be reached along the line of movement within a certain fixed time, i.e., that is at a certain temporal headway). Because this criterion does not take into account any movements of the obstacle itself it will lead to system activation in cases that are not or will not develop into collision configurations.

(2) A ***momentary*** collision configuration criterion, that is, a combination of distance, bearing angle and relative velocity (and possibly acceleration) that will eventually result in a collision when none of these parameters is changed.

(3) A ***conditional*** collision configuration criterion, that is, a configuration that would turn into a momentary collision configuration if one of the parameters were changed in *some way to be* specified within the CAS decision logic (for example, the sudden application of full braking power by the car in front).

3.1 The fixed time criterion

When this criterion is used a target for action is identified whenever an object is detected that would be reached, at the CAS-vehicle's prevailing speed, within a few seconds. Thus, it is not taken into account that the object may move itself. Therefore, this is a very gross criterion that may lead to large numbers of false alarms but possibly also to misses of really dangerous configurations. It is not likely that a criterion of this type will ever be implemented into a CAS designed to function under real-life conditions, although it has been suggested for application in early CAS-development.

3.2 The time-to-collision criterion

Many collision configurations occur naturally, i.e., drivers let them happen or produce them without meaning harm and with sufficient opportunity *for correction before* they *develop into something* really

critical (e.g., Janssen and van der Horst, 1988). Apart from the fact that a collision configuration exists per se, therefore, an absolute time-to- collision criterion would have to be part of the decision logic of a CAS using a momentary collision configuration criterion. Several authors (van der Horst, 1984; Hydén, 1987) have provided evidence that a time-to-collision criterion of 1.5 seconds distinguishes configurations that have unintentionally become critical from those that have not. This would therefore constitute a suitable candidate interval to form part of a CAS's decision logic. While the time-to-collision criterion is undoubtedly more sensible than the indiscriminative fixed time criterion it may have consequences associated with it that are counterproductive. Speaking of a longitudinal CAS, suppose there is in normal car-following behavior some distribution of time-to-collision (TTC) as in Fig. 2. The distribution may either apply within or between drivers: this is immaterial to the argument.

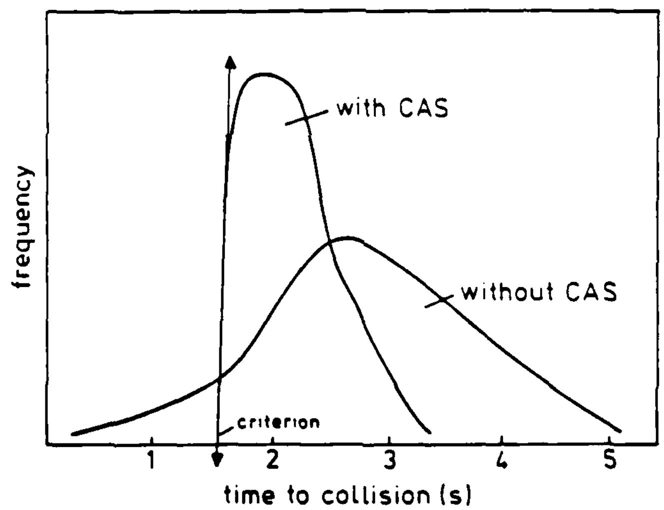

Fig. 2 Hypothetical effect of CAS on distribution of time-to-collision.

Actual magnitude of TTCs is also immaterial, as is the criterion TTC assumed here (1.5 s).

If drivers are warned whenever TTC < 1.5 s then either or both of the following could happen:

(1) While drivers will avoid TTCs below 1.5 s they will also start compressing the distribution from the right- hand side because they ***know*** they will be warned before things ever get critical. (It is left out of consideration here that, for the same reason,

drivers may already start generating more TTC-configurations per se than without the CAS.)

(2) For this last reason drivers could also become less attentive, the consequence being a simultaneous shift in their distribution of reaction times toward longer intervals.

Admittedly the effect of (1) could be that turbulence in a stream is effectively decreased. At the same time, however, collision frequency would not have to decrease at all, which will only be aggravated by the reaction time shift of (2). The net effect could, therefore, be a gain in mobility (flow), but not necessarily in safety: a trade-off that is observed to occur very often in the behavior of people subject to a safety countermeasure. Of course, the reasoning given here needs empirical testing.

3.3 Conditional criteria

A "worst case" criterion could serve a useful function in a CAS if it could reliably anticipate upon more or less plausible actions, displayed by ***the obstacle to be avoided***, that would worsen the situation. One might for an example think of a car-following situation for which the CAS is programmed to expect full braking by the leading car at any moment. (For two vehicles driving in the same direction with approximately equal velocities the conditional criterium in fact amounts to the temporal headway between the vehicles being below or above the following driver's reaction time.)

It will be clear that a "worst case" conditional criterion generates plenty of false alarms, though it will also signal most or all configurations that will really become critical. Whether the discrimination of significant objects will show a net improvement is, therefore, impossible to say from armchair considerations. Likewise, the expectation of counterproductive behavioral and reaction-time effects as described under § 3.2 will have to be subjected to empirical tests.

3.4 An a priori comparison of different CAS criteria

It is possible to calculate following distances at which further action is judged necessary by a longitudinal CAS as a function of each of the three criteria discussed thus far.

For vehicles driving in the same direction at velocities $v1_t$, $v2_t$ (where 1 is the leading and 2 the following vehicle), with maximum

braking deceleration $a1_{max} = a2_{max} = a_{max}$, and with a reaction time τ of the following driver the following inequalities may be derived for the distance between vehicles d_t to be met in order for a certain criterion temporal interval c to be met in turn:

For the fixed-time criterion:

$$\frac{d_t}{v2_t} \leq c \qquad [1]$$

For the TTC-criterion:

$$\frac{d_t}{v2_t - v1_t} \leq c \qquad [2]$$

For the "worst case" conditional criterion the criterion is in terms of the distance between vehicles at time t:

$$d_t \leq \frac{\frac{1}{2}\,(v2_t^2 - v1_t^2)}{a_{max}} + v2_t \cdot \tau \qquad [3]$$

Fig. 3 shows illustrative results for the car-following situation where $v1_t = 80$ km/h, $v2_t$ varies between 75-110 km/h, $a_{max} = -7$ m/s^2, and $\tau = 1.0$ s.

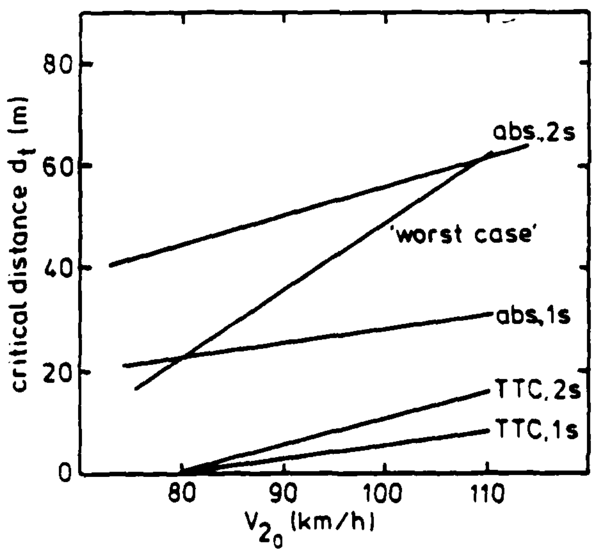

Fig. 3 Illustrative results of application of different criteria for CAS-action. TTC, 1 s and TTC 2 s: Time-to-collision criterion of 1, resp. 2 s; abs., 1 s and abs., 2 s: Fixed time criterion of 1, resp. 2 s "worst case": criterion in which it is assumed that vehicle in front can brake at any moment with maximum braking power.

What is clear from these outcomes is that the TTC-criterion will give rise to considerably less alarm rates than both other criteria (while it will not miss significant configurations). The calculations may be refined by incorporating momentary vehicle accelerations in equations [1]-[3]. However, this does not appreciably change the pattern that is apparent from Fig. 3.

3.5 Conclusions and implications for research

All reasonable criteria that activate a CAS lead to considerable numbers of false alarms, i.e., they trigger the system in many more cases than those in which an actual collision would ensue. This they must do because it is impossible to pinpoint the one critical instance per four or five driver years one really would wish to avoid, except in a too late stage.
Consequences of high false-alarm rates are, apart from possible phenomena of mistrust and irritation, that people get to use them as cues on which to base new forms of behavior. Therefore the first question to devote experimental effort to must be what the behavioral effects are of different CAS-criteria. This could most appropriately be investigated by means of a simulator study.

4 CONTENT AND ALLOCATION OF EVASIVE ACTIONS

Apart from the criterion problem there is the issue of what action will have to be performed in case a critical configuration is identified, in particular, what form of allocation should be chosen so as to divide the burden of further action between the driver and the system. The following are conceivable solutions:
(1) The system continuously displays the critical (temporal) parameter.
(2) The system warns whenever the criterion is met.
(3) In addition to (2): the system does a suggestion as to what an appropriate action could be whenever the criterion is met.
(4) The system does an active suggestion which the driver cannot neglect, but which he can overrule by an action of his own choice.
(5) Total system take-over, that is, an evasive action is started that cannot be overruled by the driver.
Intermediate forms exist: there is a clear-cut dimension of amount of system take-over, ranging from "none" to "total".

4.1 Displaying the relevant variable

As an addition to other in-vehicle displays showing relevant information which people cannot estimate reliably it might be considered to display a chosen temporal criterion variable continuously. The criterion itself might receive a mark on the scale (effectively functioning as a warning).

4.2 Warnings

If the critical variable is only displayed when the criterion is met, or if there is then some external signal indicating that this has happened, a warning is presented to the driver.
When a warning mode has to be selected as part of CAS decision logic there is a choice, as in navigation systems, between visual and auditory warnings. Visual warnings are more likely to be missed, unless they are placed in a very prominent position. Then, however, they could well take-up valuable visual capacity to be used in the evasive action itself. Auditory warnings cannot easily be neglected (and they do not take-up visual capacity). It is precisely for this reason, however, that auditory false alarms can be very annoying.
The opposite side of the coin, already elaborated upon in § 3.2, is that an effective warning is a mixed asset in a self-paced task like automobile driving. That is, the warning itself - if not already neglected because of numerous false alarms - may become a cue to regulate behavior by, with unsure outcome. It may also become the case, in case of not too accurate timing, that the driver has already started an action that is then interfered with by a warning.

4.3 Suggestions and active controls

Braking and/or swerving is the appropriate action in impending collision configurations. Active controls in the CAS-vehicle may assist the driver by already beginning to perform whatever is deemed best in the particular situation. The design of these controls, which comprise the ***smart accelerator pedal*** and the ***smart steering wheel***, is also dealt with in the GIDS-project. Their distinctive feature is that the active control, after it has started its action, may be overruled by the driver, so that it is the driver who retains ultimate decision power.
The obvious advantage of active controls is that they may reduce driver reaction times in critical situations. The other side of active

controls is that the control must be pretty sure that it is indeed performing the appropriate action. Otherwise the driver loses valuable time while busy overruling the control. False alarms, when generated by active controls that are too active, might also be a matter of concern. Thus, setting the criterion for action at exactly the right level is even more critical than for a "warning only" CAS. It should be realized that there is also a qualitative problem here in that there may be cases in which swerving is a more adequate reaction than braking, that the system's decision logic should recognize this, and that it should also be able to apply a correct "dosage" to the control. Finally, behavioral adaptations may occur once the driver knows that there is an active control guarding him. The experience with ABS, which is also an active control system, has shown that these effects are indeed to be expected.

Going halfway back from "active controls" to mere warning there is the possibility that the CAS-system makes ***suggestions*** only. This would include the same decision logic as in the active case. Because the action is not actually performed some of the problems can be avoided that are associated with active controls. Then again there will be situations in which the suggestion is so trivial that the driver would really have been helped much more by *actually starting to exert it* (e.g., an impending rear-end collision, where it is not so much a question of being told to reduce speed as to do it quickly enough).

Given the questions and considerations as above there must be performed empirical investigations as to whether there is an optimum in the design of active controls and/or in the presentation of suggestions, and how this relates to the other ways of allocating decision power.

4.4 Total system take-over

The assumption underlying automation is that machines can always be made more reliable and more predictable than humans, and that it therefore always makes sense (in terms of safety) to replace humans by machines where that is technically feasible.

In her paper "Ironies of automation" Bainbridge (1982) lists a number of unexpected consequences automation may have, some of which may be applicable to the case of a fully automatic CAS. Prominent among these is that any automatic system must be really fail-proof. As indicated earlier it will be difficult to have the system surpass the near-to-perfect performance of even the average driver. Even if the decision logic were perfect the system may have technical malfunctions, and it

will need maintenance, replacement of parts, checks of its proper functioning, etc., that cannot be automated and that can cause operating errors. And because the driver will no longer have the capability to handle dangerous actions - these being taken away be the usually flawless performance of the automaton - he will not be able to detect and to compensate for possible errors. Finally, it is to be expected that drivers having a fully automated CAS will more often get into critical situations from which even the automaton will not be capable of getting them out.

As with the other means of allocation discussed thus far, however, there are no reasons to reject automation in principle. It is only by empirical investigation that it can become apparent what the type and the extent of possibly negative consequences are, to compare these to the positive effects, and to see whether there is some optimal balance between these two classes of effects.

4.5 Conclusions and implications for research

A major question to be considered in the design of a CAS is how to allocate the decision to take action and to put it in one form or another. There is a continuum ranging from a mere display of relevant information to the driver to total take-over by the CAS. Any choice of a point on this continuum has its advantages and disadvantages, which are impossible to evaluate on an a priori basis. It is therefore necessary that experimentation be conducted to find the optimum, if there is any.

5 EMPIRICAL EVALUATIONS OF COLLISION AVOIDANCE SYSTEMS

To the knowledge of the author there have to date been three empirical investigations that could be said to bear on the behavioral aspects of a CAS. These are by Leutzbach et al. (1984) and Panik (1984) in Germany, and by Malaterre and Saad (1986) in France (though these authors tested one particular CAS of German origin). All of these have used existing (prototype) systems, so that there really has been little variation on the critical dimensions described above. Yet they have resulted in findings which should form at least a beginning of evidence on the behavioral and safety effects to be expected from a CAS.

5.1 Panik (1984)

This investigation compared the effects of different CAS warning strategies on car-following behavior in a simulator.
It is not stated in the report what the criterion for warning was. There was an ***acoustical*** warning (a tone), an ***optical*** warning (a red light) and a ***proprioceptive*** warning (this being the "smart" accelerator pedal mentioned in § 4.3).
The task to be performed was to follow vehicles the driver found himself to be behind.
The dependent variable in the study was the proportion of total driving time in which the following driver was in a danger zone, defined as being so close to the vehicle in front that a collision with a velocity difference of ≥ 10 km/h would follow in case of sudden full braking by the leading car. One may suspect, although this is not stated, in the paper that this was also the criterion maintained in actuating the warning.
Fig. 4 shows the results. It is apparent that the acoustical warning kept drivers out of the (conditionally) critical zone most often. The proprioceptive and the optical warning modes were about equally efficient in accomplishing this, though clearly less so than the acoustical warning.

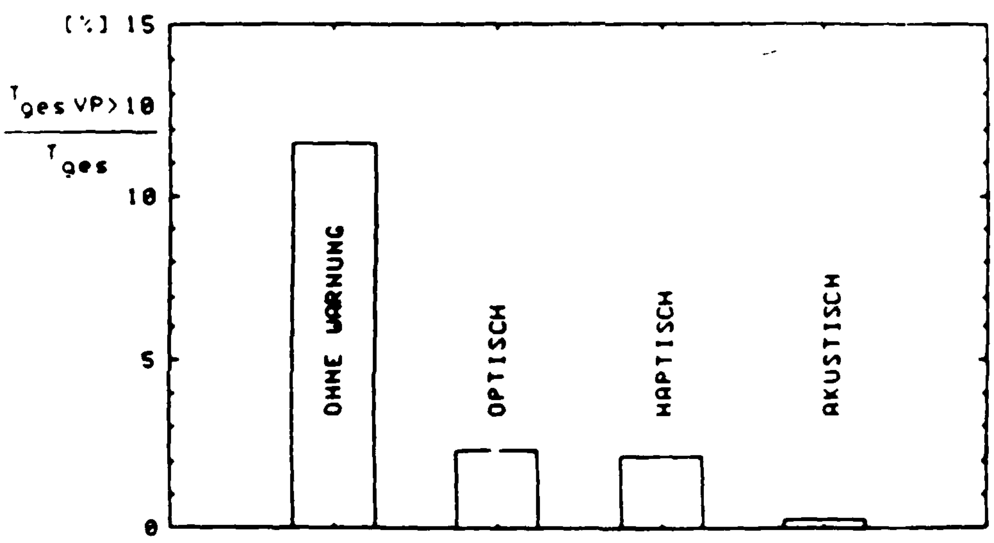

Fig. 4 Results of Panik (1984) study on warning modality in car-following.

It must be noted that this seemingly clear-cut result does not permit a direct extrapolation to possible beneficial safety effects. The

acoustical warning in particular may have served as an efficient - and unavoidable - cue to compress the distribution of headways, as explained in § 3.2, with an indeterminate effect on safety.

5.2 Leutzbach et al. (1984)

In this investigation a number of passenger cars and light trucks were fitted with a "distance warning device". The authors set out by stating that the safety distance was calculated under the assumption that the vehicle ahead would brake with the maximum deceleration until coming to a dead stop and that the vehicle following, after a reaction time of the driver, should then just be able to avoid a rear-end collision. That is, the authors describe a "worst case" conditional criterion like that - presumably - applied in the Panik study.
However, later on in the paper the authors - instead of giving an exact determination of the safety distances - mention that a warning strategy for the field study was developed which represented a compromise between safety requirements in various traffic situations and acceptance of the warnings by the driver. Unfortunately, this is not explained in further detail.
Results are reported in the paper of test runs performed both on motorway and rural highway sections, comprising both straight and curved paths, and on a section of city road with typical city traffic conditions.
Fig. 5 shows numbers of alarms provided by the CAS, and how many of these were false alarms. It is not clearly stated by the authors what they considered to be "false alarms". Presumably this must have been cases where there was not a vehicle within the safety distance, where oncoming vehicles were signaled, etc.

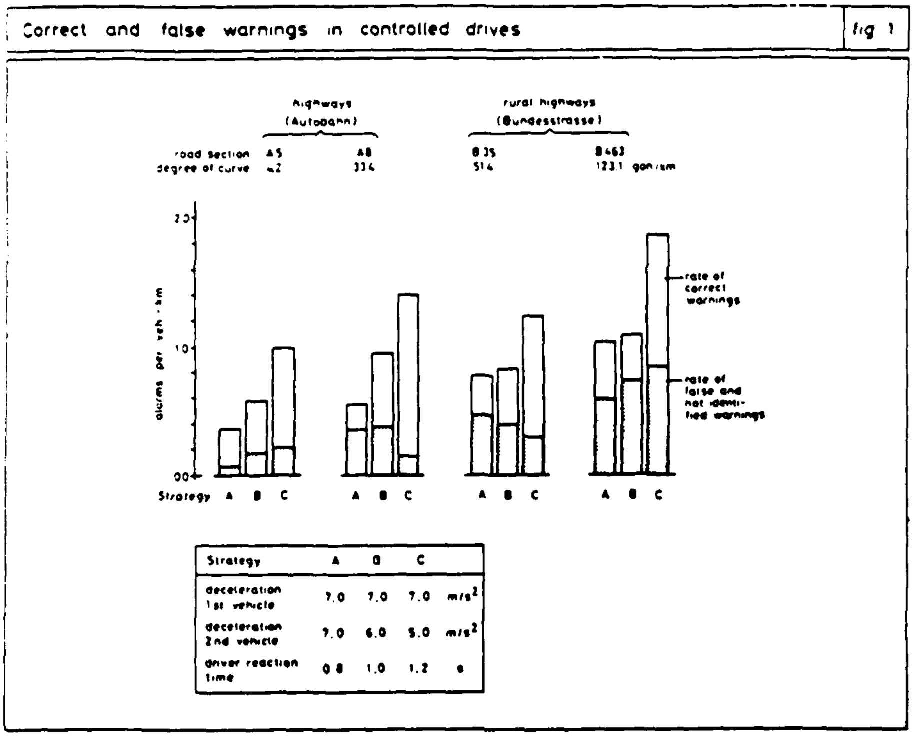

Fig. 5 Alarm and false alarm rates obtained in Leutzbach et al. (1984) study.

In any case, absolute numbers of alarms were very high (between ± 0.4 and ± 1.8 per km driven!), and the false alarm rate was in the order of 50% in some of the test conditions. Although this is not apparent from the data as they are presented in the paper, and although it is not elaborated upon, the authors note that drivers with a warning system might conceivably follow an "alarm avoidance strategy" when they know how the device works.

5.3 Malaterre and Saad (1986)

The device tested in this investigation is shown in Fig. 6. A series of LEDS continuously indicated headway (presumably in the temporal sense) on the basis of radar measurement. Number and color of LEDS changed with decreasing headways, from green to yellow to red. It is not stated by the authors what the criteria for a change in color were, though one may suspect from the text that it was a conditional ("worst case") criterion. The device simultaneously furnished acoustic signals. The "serious" signal indicated that LEDS got into the red

zone. The "light" signal indicated a relative velocity difference of over 5 km/h.

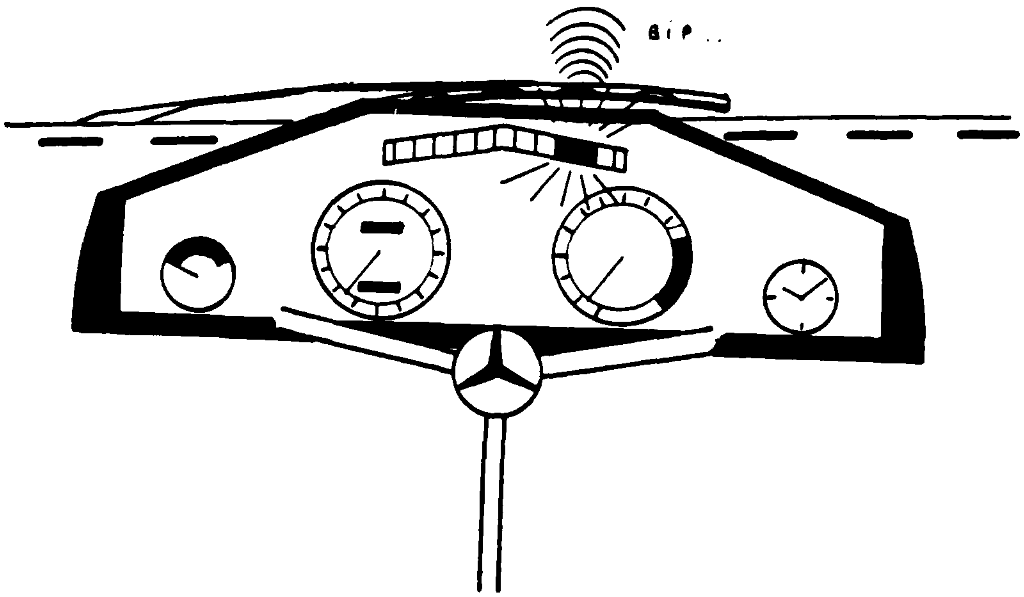

Fig. 6 Headway indicator as used in Malaterre & Saad (1986) study.

Tests with this device were performed under real driving conditions. The description of the results in this paper is so anecdotal and qualitative that it does not lend itself to derive suggestions from which future experiments could benefit.

5.4 Conclusion

From the three (more or less) behavioral CAS-studies reported in the literature one can obtain some bits and pieces of evidence to have in mind when starting research efforts within GIDS. Generally speaking, however, the studies show a surprising vagueness in the description of even the essential parameters.

6 GENERAL CONCLUSIONS

As will have become apparent it is not difficult to raise questions bearing on the design and functioning of a CAS. Research should be

directed to answering these questions, and it will come down to the evaluation of more or less foreseeable behavioral consequences of either a favorable or a counterproductive nature. Two essential issues have been identified that must be resolved if there are going to be benefits from the potential of anti-collision technology, one being that of the appropriate criterion for triggering system action, the other that of what form action should take and who should perform it.

Given the relatively long history of the development of anti-collision systems for road vehicles it is surprising that so little has been done on precisely the behavioral effects which will determine any system's ultimate success. Moreover, what has been done seems to be most of a trial-and-error nature. It appears that we have to begin almost from scratch as far as behavioral effects are concerned.

Experimentally testable expectations have been derived in this paper from which sensible behavioral studies to be performed within the GIDS-project follow naturally.

The first (simulator) study will compare the effects of different (longitudinal) CAS criteria on driver behavior. As a secondary variable, and as an introduction to an experiment specifically to be devoted to the "allocation" dimension, it will compare the effects of several display and warning strategies (i.e., in the auditory versus visual versus proprioceptive modalities). Parallel in time with this first simulator study, a "baseline" car-following study will be performed which will anticipate on later field studies with a prototype CAS. This baseline study will describe behavior as it is without a CAS, so that the effects of a CAS on actual behavior can effectively be evaluated.

Results obtained in the empirical studies will have to be consolidated in the form of a model of driver behavior in the manoeuvering subtask. This is not a means by its own, however, but an essential requirement to incorporate manoeuvering knowledge in a GIDS-prototype. Therefore, the theoretical consolidation of empirical findings will have to be part of the effort right from the start, and it will have to continue throughout the project.

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The impact of collision avoidance systems on driver behavior and traffic safety: Preliminaries to studies within the "GIDS"-Project

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14. SUPPLEMENTARY NOTES

15. ABSTRACT (MAXIMUM 200 WORDS, 1044 BYTE)

This report reviews the essential considerations in the design of anti-collision systems for use in road traffic, in terms of the expected effects on driver behavior and, consequently, on traffic safety. The two critical questions that should be answered before any CAS could function in a sensible way are:
(1) What is the criterion for system activation?
(2) What action will subsequently have to be performed?
Different criteria for activation, while all in temporal terms, will give rise to different rates of alarms and of false alarms. A priori calculations are given for fixed time criteria, time-to-collision criteria, and worst-case criteria. A time-to-collision criterion must a priori be judged to be most adapted to "natural" driving behavior. With respect to the actual action to be undertaken, the choice is among different levels of system take-over, where the variation is from "none" to "total". Although total take-over by an automatic device sounds attractive there are difficultirs associated with it which have already been identified in other forms of man-machine interaction, e.g., behavioral changes counteracting the favorable effects to be obtained by automation. Empirical evidence will have to assist in the ultimate decision of what level of take-over should be considered optimal.

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